STANDARDIZATION OF QUALITY STEEL

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ABSTRACT: The basic conditions for standardization of quality and special steels and alloys are presented. Classified groupings of brands of steel used when developing standards and their effect on the system of designating brands for standardization are covered.

Basic technical terms and concepts in the field of standardization are covered. Brief characteristics of basic effective state standards, reasons for their development and basic distinctive peculiarities, methodical instructions on questions of developing standards and technical specifications are given. Separate questions of international standardization are covered.

The book is intended for engineers and scientific workers in the ferrous metallurgy and various branches of machine building.

New Methods of Production and New Quality Factors for Standardization

The production of steel using new progressive production processes solves two main problems, which, in the final analysis, have a single purpose--the improvement of productivity of work, on the whole, in the national economy.

The first task is increasing productivity and improving the production and economic factors at metallurgical factories, preserving a certain level of quality in the metal established by existing standards and technical specifications; the second is increasing the quality of production--of steel semimanufactured products by adopting new production processes which provide long life and reliability of machines and structures made from them.

The solution of the second problem is directly reflected in standards and technical specifications by fixing qualitative factors of materials obtained by new production processes.

In recent years new methods of refining steel have been broadly expanded--treatment in the ladle with liquid synthetic slag, electro-slag and vacuum-arc remelting, melting in vacuum induction furnaces and extra-furnace degassing.

After a thorough study of metal obtained by the new methods in laboratory

conditions one must test its service properties, that is deliver the metal to the consumer and carry out the necessary test stand and full-scale testing.

The first test batches of metal melted using the new methods were delivered to the consumer according to existing technical specifications for the production of analogous brands and assortments of steel melted in open electric and open-hearth furnaces.

Delivery according to existing technical specifications made it possible for the consumer to obtain products with a quality "not lower" than that formerly established. Distinctive labeling of metal melted using new methods adding to the brand the indices SSh [sinteticheskiy shlak, synthetic slag]--processing with synthetic slag, Sh [electroslakovyy pereplav, electro-slag remelting] electro-slag remelting, VD [vakuumno-dugovoy pereplav, vacuum-arc remelting]—vacuum-arc remelting, VI [vakuumnaya indukttsionnaya vyplavka, vacuum induction melting]—vacuum induction melting, made it possible to establish careful observation of "the behavior of the metal" for all ranges for the supplier and consumer and to clarify their qualitative advantages which in the final analysis must be reflected in standard specifications.

Gradually special technical specifications began to be created for specific brands of steels and types of production.

Processing metal in the ladle with synthetic slag (SSh) is broadly used in plants for the production of quality steel of a wide assortment. When using this method, contamination of the steel with nonmetallic inclusions is decreased and, correspondingly, the appearance of hairline cracks. The content of sulfur in the metal is decreased by almost 2. The mechanical properties of samples cut crosswise to the grain is considerable improved and accordingly the uniformity of mechanical properties is increased (Table 74).

TABLE 74 ANISOTROPY OF CHARACTERISTICS OF PLASTICITY AND DUCTILITY OF STEEL [51]

(a)	(b)	(c)	(d)/(e)	(d)/(e)	(d)/(e)
(1) 40ХНМА	10 10	(2) Э ЭСШ	0,91 0,78	0,76 0,7-	0,51 0,63
(3) 30ХГСА	8 6	(2) Э ЭСШ	0,61 0,7-	0,76 0,71	0,60 0,75
(4) 38ХМЮА	12 4	(2) Э ЭСШ	0,-0 0,8-	0,71 0,8-	0,75 0,85

Key:
a. Brand of steel
b. Number of test melts
c. Steel (method of melting)
d. Crosswise
e. Lengthwise
1. 40KhNMA
2. E [Electro, electric] : ESSh [Electro-sinteticheskiy shlak, Electro-synthetic slag]
3. 30KhGSA
4. 38KhMYuA

As a result of using this method of production the amount of rejected material is decreased in hard to eliminate defects of metallurgical cause, for example, ghosts in brand 38KhMYuA steel. Special technical specifications were worked out for structural steel melted using refining with liquid synthetic slag which provided standards for mechanical properties for crosswise samples and a low content of sulfur. However later on it was recognized that it was not suitable to create special technical standards for steel in the SSh category because this method of improving steel is used very widely for steel of various brands for various purposes.

At the present time, in standard specifications and even in the standards the possibility of using this production process for providing a given level of quality is pointed out.

Electro-slag remelting--EShP [Electro-shlakovyy pereplav, electro-slag remelting] allows one to obtain a metal of high quality, considerably more

dense and uniform in comparison with electro-metal with a lower content of gases and nonmetallic inclusions. The use of electro-slag metal in machine building made it possible to improve the life of many engines and machines. The production of certain steels and alloys began to be possible only after the mastery of the EShP method because when melting these steels in open furnaces the yield of suitable metal was exceptionally low because of low ductility for hot mechanical processing and poorer surfaces.

Electro-slag metal in the adopted process are delivered in parallel with metal from open melts according to the same technical standards: however, at the present time one can correctly consider that the brands of steel and alloys marked with the Sh index are essentially independent new brands with distinctive qualitative factors which are apparent not only during operation but also in delivered condition. Moreover, there are brands in the Sh category which do not even have doubles in open melting because production of these steels in electric furnaces and open-hearth furnaces are not suitable.

After 1967—1968 about 40 standard specifications for steel with the Sh index brand were established: structural, ball bearing, corrosion-resistant, heat-resistant.

Technical specifications stipulate special requirements in macrostructure including hairline cracks, standardize nonmetallic inclusions, establish narrower limits for the content of carbon and sulfur.

Table 75 gives a comparison of the requirements of technical specifications for corrosion-resistant steel of a single type for ordinary and electro-slag brands.

For sheet steel brand EI652Sh the standard for relative elongation determined at 200°C is established at 10% (absolute) higher than for sheet steel brand EI652.

TABLE 75 THE REQUIREMENTS OF TECHNICAL SPECIFICATIONS FOR CORROSION-RESISTANT OPEN MELT AND ELECTRO-SLAG STEEL

(2)	(b)	
	(c)	(3)
(1)	≤0,025	≤0,015
(2)	≤0,025	≤0,020
(3)		
(4)	(5) Не нормируется	1
(6)	(7) То же	1
(8)	» »	1
(9) Неметаллические включения, балл:		
(10) оксиды	(11) Не ограничивают ся	1,0
(12)	(7) То же	1,5
(13) сульфиды	» »	1,0
(14)	» »	1,0

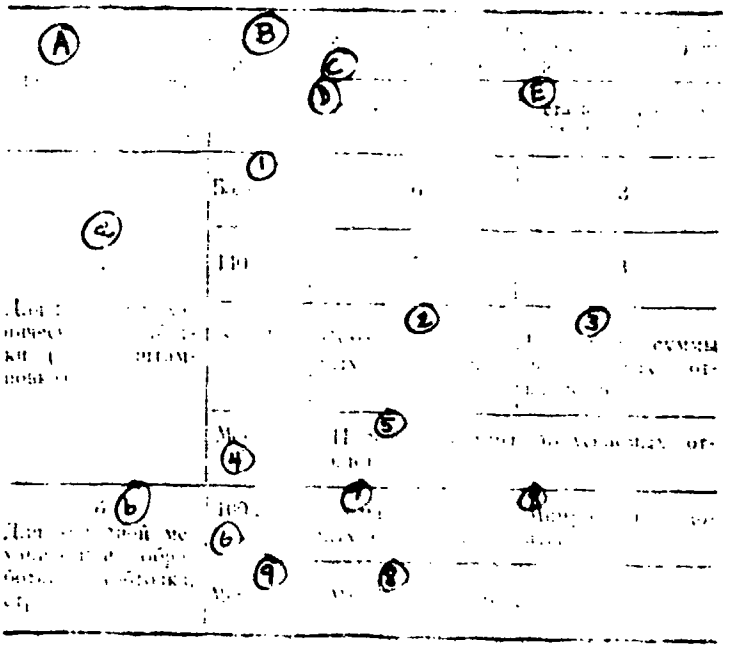
Key

a. Qualitative characteristics
b. Standards established by technical specifications
c. Electro-metal
d. Electro-slag metal
1. Content of sulfur
2. Content of phosphorous
3. Macrostructure, points:
4. Shrinkage porosity
5. Not standardized
6. Point inhomogeneity
7. Ditto
8. Segregation square
9. Nonmetallic inclusions, points
10. Oxides
11. Not limited
12. Silicates
13. Sulfides
14. Globular

On the basis of compilation of factual results of testing structural alloy steel of various brands in a State Standard project for structural alloy steel, special factors of quality were included for EShP metal. For example, the acceptable depth of surface dressing of EShP metal is accepted to be twice as small as for metal from open melts (Table 76).

Requirements for macrostructure in EShP steel are accepted as 3 times more rigid than for a quality steel and twice as rigid as for high-quality steel (Table 77).

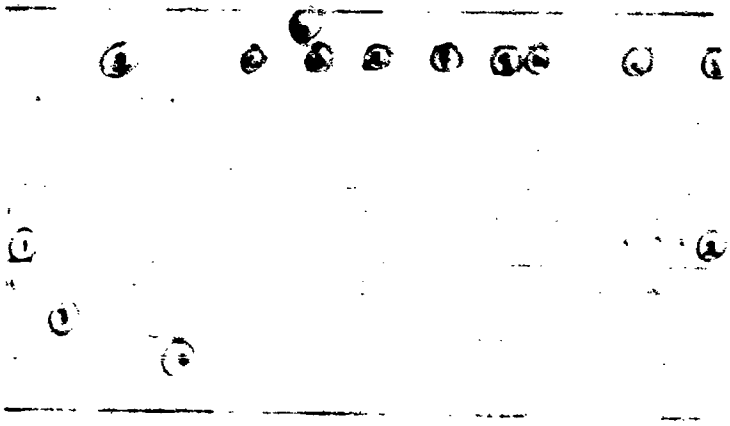
TABLE 76 STANDARDS FOR DEPTH OF SURFACE DRESSING FOR STEELS OF VARIOUS CATEGORIES OF QUALITY



Key:

A. Purpose of the group
B. Dimension of rods, in mm
C. Depth of surface treatment (for group a) or depth of underlying defects (for group b), mm or percent of the dimensions, not more than
D. Quality and high-quality steel
E. Electro-slag remelt steel
a. For hot mechanical treatment (forge, stamp)
1. More than 200
2. Total of permissible deviations
3. Half of the total of permissible deviations
4. Less than 80
5. Half of the total of permissible deviations
b. For cold mechanical treatment (turning, line)
6. 100 and more
7. Total permissible deviations
8. Negative tolerance
9. Less than 100

TABLE 77 STANDARDS FOR MACROSTRUCTURE, FOR STEEL OF VARIOUS CATEGORIES OF QUALITY



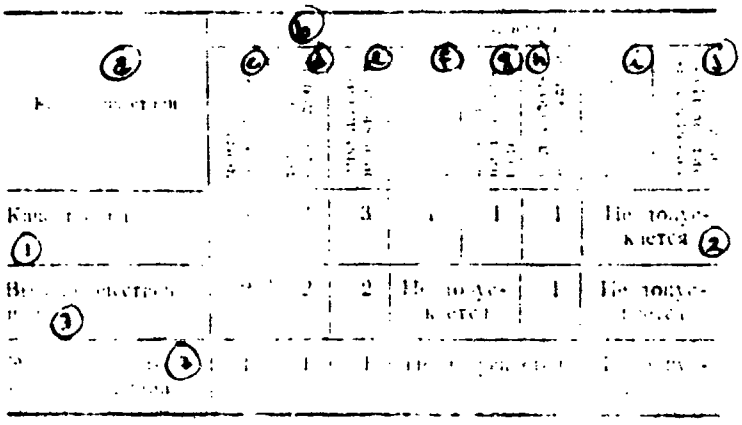
Key:
a. Category of steel
b. Permissible point, not more than
c. Shrinkage porosity
d. Point inhomogeneity
e. Segregation square
f. Total point segregation
g. Outer point segregation
h. Sub-charge segregation
i. Subcrust bubbles
j. Inter-crystalline cracks
l. Quality
2. Not permissible
3. High-quality
4. Electro-slag remelting

Standards for hairline cracks for EShP steels adopted are three times less than for quality steel (Table 78).

Standardization of vacuum-induction melt and vacuum-arc remelt metal was made just like that for EShP metal; that is, the majority of types of production were prepared in the form of test melts and delivered according to existing technical specifications; however, for certain types of production special technical specifications were worked out immediately with more rigid requirements. Such technical specifications were specifications for delivery of steel for instruments and special bearings. A special requirement for the steel for such a purpose was a high degree of purity from nonmetallic inclusions which could not be attained for ordinary electric steel.

For testing contamination of ShKh15P steel (instrument) for nonmetallic

TABLE 77 STANDARDS FOR MACROSTRUCTURE, FOR STEEL OF VARIOUS CATEGORIES OF QUALITY



Key:
a. Category of steel
b. Permissible point, not more than
c. Shrinkage porosity
d. Point inhomogeneity
e. Segregation square
f. Total point segregation
g. Outer point segregation
h. Sub-charge segregation
i. Subcrust bubbles
j. Inter-crystalline cracks
1. Quality
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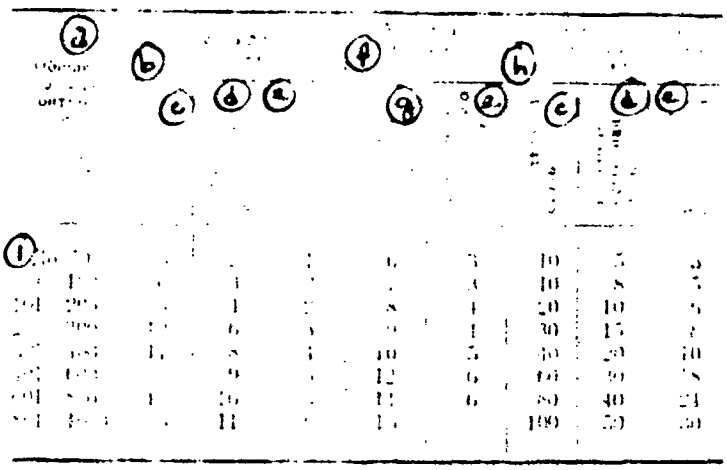
For testing contamination of ShKh15P steel (instrument) for nonmetallic

TABLE 78 STANDARDS FOR HAIRLINE CRACKS ESTABLISHED FOR STEELS OF VARIOUS CATEGORIES OF QUALITY



Key:
a. Total area of the test surface of the part, cm^2
b. Number of permissible hairline cracks
c. Quality steel
d. High-quality steel
e. Electro-slag remelt steel
f. Maximum length of hairline crack
g. Quality and high-quality steel
h. Total extent of hairline crack, mm
1. Less than

inclusions and their evaluation a special slag was created because the permissible point for nonmetallic inclusions was considerably lower than point 1 on the standard scale for evaluation of KhSh15 steel.

A new scale was created for five types of inclusions--oxides, sulfides, silicates, globular inclusions and pinhole inclusions.

A 4-point scale in which point 4 of the scale has inclusions which corresponded to point 2 of the standard GOST [Gosudarstvennyy obshchesoyuznyy, All-Union State Standard] 801--60 scale.

Figures 56 and 57 show the scales which correspond to point 1 on the standard scale and point 1 according to the technical specifications scale.

Technical specifications for ShKh15P steel or its succeeding steel called ShKh15VD specifies testing for nonmetallic inclusions on 10 samples instead of the 6 established for all other technical specifications and standards.

Figure 56. Oxides (point 1) --Evaluation According to GOST 801--60 Scale

Figure 57. Oxides (point 1) --Evaluation According to ChMTU [Chernyy metallurgicheskiye tekhnicheskiy usloviya, Ferrous metallurgical technical specifications] 1-330--67 Scale for Vacuum-arc Remelt Metal

The standards for nonmetallic inclusions established are very rigid, for example, for rod with diameter less than 25 mm the maximum point for oxides is established as not more than 1 according to the scale for the given technical specifications.

Microporocity in ShKh15VD steel is not permissible, and also increased requirements in macrostructure are established, carbide segregation and structural striation.

All the remaining factors for ShKh15VD steel must correspond to the requirements of GOST 801--60 as they are laid out for ShKh15 steel.

The method of vacuum-arc remelt has broad use for the production of heat-resistant alloys. It was established that long-term strength of metal after vacuum-arc remelting improves while the mechanical properties at room and

increased temperatures for vacuum remelt differ very little from ordinary melts and only have higher factors for ductile characteristics.

Vacuum remelting permits considerably decreasing the content of gases, nonmetallic inclusions in the metal and results in an important decrease in admixtures of nonferrous metals which is particularly important in the production of heat-resistant alloys. A decrease in content of admixtures of nonferrous metals in specific melts is presented in Table 79.

TABLE 79 THE CONTENT OF ADMIXTURES OF NONFERROUS METALS BEFORE AND AFTER VACUUM REMELTING [51]

②		Sb	Bi	Zn
①				
②				

Key:
a. Metal
1. Initial
2. Vacuum

A large number of special technical specifications were created for vacuum-arc remelt metal, whose qualitative factors have an essential distinction from the factors of analogous brands of steels of alloys melted in open furnaces.

For example, for corrosion-resistant steel supplied in the form of section rolled goods, Table 80 shows various requirements for macrostructure and nonmetallic inclusions.

Table 81 gives examples of technical specifications established for heat-resistant alloys with various requirements in mechanical properties.

TABLE 80 STANDARDS FOR MACROSTRUCTURE AND NONMETALLIC INCLUSIONS FOR STEEL WITH VARIOUS MELTING METHODS

(a) Наименование показателя, нормируемого техническими условиями	(b) Электрометалл	(c) Металл ВДП	(a) Наименование показателя, нормируемого техническими условиями	(b) Электрометалл	(c) Металл ВДП
	(d) Максимально допустимый балл			(d) Максимально допустимый балл	
(1) Центральная пористость	1	1	(5) Силикаты хрупкие	3	1
(2) [illegible]	3	2	(6) Силикаты пластичные	3	1
(3) [illegible]	3	1	(7) Силикаты недеформирующиеся	3	2
(4) [illegible]		2	(8) Сульфиды	3	3

Key:

a. Name of the factors standardized by technical specifications
b. Electric metal
c. VDP metal
d. Maximum allowable point

1. Shrinkage porosity
2. Point inhomogeneity
3. Point oxides
4. Line oxides
5. Brittle silicates
6. Ductile silicates
7. Non-deformable silicates
8. Sulfides

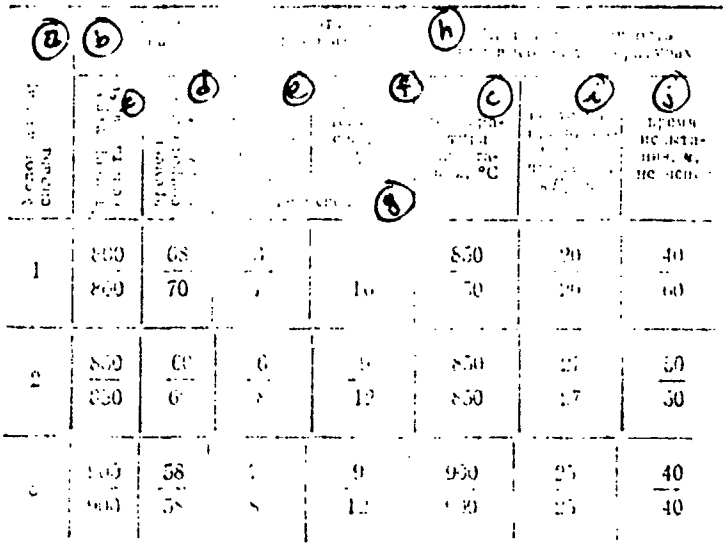
Various requirements for macrostructure are established by technical specifications. If an open melt metal has a standard of 26 calibrations for macrostructure in 38 calibrated samples, then VDP metal from the same 38 samples is permitted to have only 21; three calibrations out of four are considered permissible for open melt metal and for VDP--two out of four.

Steel and alloys melted by a VDP method are not yet standardized, that is there is no single State standard for them in which brands with the VD index have qualitative factors established for them.

This fact can be partially explained because existing criteria and factors for quality established in GOST for quality steel are not always suitable for evaluation of VDP or EShP metals.

New methods of production require evaluation of the factors. For example,

TABLE 81 MECHANICAL PROPERTIES OF HEAT-RESISTANT ALLOYS SPECIFIED BY TECHNICAL SPECIFICATIONS



Key:
a. Conditional brand of alloy
b. Short-term testing, tensile at high temperatures
c. Test temperature, °C
d. Breaking point, kgf/mm^2
e. Relative elongation, %
f. Relative compression, %
g. Not less than
h. Long-term strength at high temperatures
i. Constantly applied tension, kgf/mm^2
j. Test time, hr, not less than

Notation. Numerator--open method of melting, denominator--VDP.

when evaluating the macrostructure of steels for etched templets a new type of defect was apparent which was characteristic for EShP and VDP metals. This flaw was called "laminar crystallization" (Figure 58).

Sometimes one encounters a macrostructure with slightly increased corrosion capability in the axial zone. Point segregation for EShP and VDP metal also has specific forms (Figure 59).

The presence of new standards for evaluation of metal macrostructure obtained by new methods required the adoption of changes in existing State Standard GOST 10243--62 "Steel. Method of testing macrostructure." This change has already been developed by NIIM [Nauchno-issledovatel'skiy institut

Figure 58. Laminar Crystalization, Calibration Point 3

Figure 59. General Point Segregation Characteristic for ESRP and VDP Metal —Calibration Point 3

metallurgii, Scientific Research Institute of Metallurgy] and has been presented for approval. An analogous situation is more complex with the evaluation of nonmetallic inclusions. Existing GOST 1778--62 "Steel. Metallographic method of evaluation of nonmetallic inclusions" turned out to be too "coarse" for evaluation of VDP metal; therefore a decision was made to rework the standard mentioned. A plan for a new standard is being developed at TsNIICHM [Tsentral'nyy nauchno-issledovatel'skiy institut chernoy metallurgi, Central Scientific Research Institute of Ferrous Metallurgy].

One of the new melting methods is also melting in vacuum induction furnaces. This method has already been partially expressed in state standards. In particular, in standards for alloys with a certain coefficient of thermal expansion, qualitative requirements have been planned for alloys 29NK-VI, 30NKD-VI and 47ND-VI.

For more successful work in the field of standardization of steels and alloys melted by new methods, it is necessary to broaden work on clarifying new factors for quality and correspondingly developing new methods of testing and accumulation of factual results of testing done by new methods.